INTEGRATING TEACHABLE MACHINE IN ROBOT LINE FOLLOWER USING ARDUINO UNO

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I. BACKGROUND OF THE STUDY

Improvisation in sensor technology, control algorithms, and integration with contemporary computing devices have made significant advancements in line follower car robotics. Highly susceptible line detection and improved data acquisition can be achieved with the use of complex infrared sensor arrays [5].

Using Arduino to integrate a line follower robot requires a few essential parts and steps. By distinguishing between black and white surfaces, the infrared (IR) sensors identify the line. They then transmit signals to the Arduino, which uses the motor driver to control the motors and change the robot's direction [3]. These robots are widely used in manufacturing and warehousing for automated material handling, reducing human labor in repetitive tasks such as transporting goods. In healthcare, they assist in delivering medications and supplies within hospitals, proving especially useful during the COVID-19 pandemic by minimizing human contact [6][11]. Additionally, they are employed in educational settings to provide hands-on learning experiences in robotics and automation, and in agriculture to guide machinery for planting and harvesting [9].

However, despite being a popular choice for line follower robots due to their affordability and ease of use, infrared (IR) sensors come with several drawbacks [4]. Because of their extreme sensitivity to ambient light, these sensors can become less accurate and cause interference, especially in different lighting situations. Furthermore, the limited detection range of infrared sensors—typically less than 1 centimeter—makes them less useful on surfaces that are uneven or reflect light, which may distort their readings. Furthermore, reducing the sensors' dependability in a variety of settings is their inability to reliably detect lines on glossy or dark surfaces [7]. Finally, the line follower robot's performance can be negatively impacted by an incorrectly configured IR sensor setup, which can cause unpredictable behavior [1].

In light to this, in robotics, replacing conventional infrared sensors with machine learning and tools such as Teachable Machine offers significant benefits. Robots that perform tasks like line following can be more flexible and dependable thanks to machine learning algorithms, especially those that are based on neural networks. These algorithms can learn from and adapt to a variety of environmental conditions on their own [2]. Using straightforward examples and feedback loops, Teachable Machine, an intuitive platform for training machine learning models without deep programming experience, democratizes the creation of unique vision-based systems [9].

This is why the researchers opted to incorporate Teachable Machine into a line-following robot using Arduino Uno. Through the integration of machine learning and Teachable Machine, robots equipped with vision-based capabilities can attain superior accuracy, adaptability, and strength in line-following tasks, surpassing traditional IR sensor-based systems.

II. OBJECTIVES OF THE STUDY

The primary focus of this study is to explore and elucidate the methodology of robot line follower utilizing a teachable machine. Through robot line follower, the study intends to identify and delineate thematic structures embedded within the algorithmic design and operational mechanics of autonomous navigation.

1. To implement Teachable Machine in replacement of traditional line-following sensors to improve the performance of the robot's navigation.
2. To configure the robot so that it advances forward automatically whenever it detects a straight line, ensuring consistent and accurate movement along the path.
3. To program the robot to execute a right turn whenever it detects a signal indicating a right turn, ensuring precise maneuvering in response to directional changes.
4. To ensure the robot can accurately navigate and complete the lines within its environment, effectively following the path to its end.

III. METHODOLOGY

In recent years, the traditional line following methods for robots, often relying on simple line sensors, have limitations in complexity and adaptability. This project sought to overcome these limitations by utilizing the power of teachable machine. The researchers present the methodology employed to develop and implement a line following system for a robot, powered by a teachable machine. This methodology outlines a comprehensive approach to discovering insights through the integration of teachable machine in robot line follower, this includes the collection of data, model training/development, Arduino development, model integration, and model evaluation. This section will delve into the heart of the system, the intelligent core responsible for real-time decision-making and precise navigation.

Figure 1: Project Workflow

Materials

The construction of the robot line follower was built and tested. The different parts were connected and tested together. The following are the main components used.

a. Arduino UNO

b.Wi-Fi Module

c. Programmable Car Set

d. L298N Motor Driver

Data Gathering

This is the phase where the researchers gathered the data from the environment that they have created solely for the purpose of providing an interactive place or structure for the robot line follower. The researchers utilized mobile phone–iPhone 14–in capturing the images from the environment but any type of mobile phone would do. These will cover a wide range of images capturing the paths of the environment, thereby offering significant data for analysis.

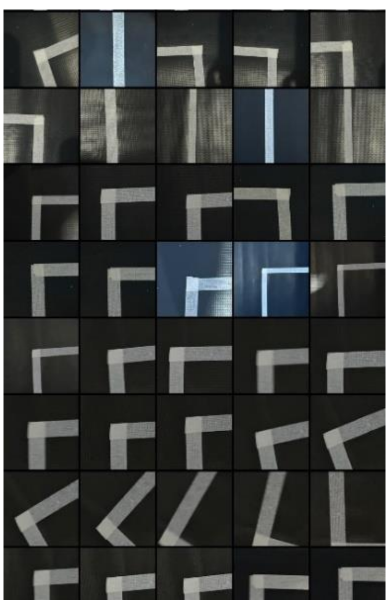

Figure 2. Sample Images from the Environment

Model Development

In this stage, the preprocessed images is transformed into a numerical format suitable for machine learning algorithms. Techniques like Term Frequency-Inverse Document Frequency (TF-IDF) are employed to weigh the importance oof terms within the documents. Moreover, since LDA has an inbuilt TF-IDF vectorizer, the researchers will have to use Count vectorizer.

Arduino Development

The construction of the robot line follower was built and tested. The different parts were connected and tested together. The following are the main components used.

a. Arduino UNO

Arduino is an open-source platform with user-friendly hardware and software. It uses the Microchip ATmega328P microcontroller and offers 14 digital pins, 6 analog pins, and a reset pin. It can be programmed using the Arduino IDE via a type B USB cable. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or ide (Integrated Development Environment) that is used to write and upload computer code to the physical board

Figure 3. Arduino Uno

b. Wi-Fi Module

A Wi-Fi module is a component that enables devices to connect to wireless networks and communicate with other devices or the internet. It integrates Wi-Fi functionality into devices that wouldn't otherwise have it, allowing for wireless data exchange. These modules often come with built-in protocols and security features, making them essential for IoT (Internet of Things) applications, remote control systems, and wireless data transmission.

Figure 4. Wi-Fi Module

c. Programmable Car Set

A programmable car set typically includes a chassis, motors, wheels, and electronics designed for educational purposes and prototyping. These kits often feature programmable microcontrollers like Arduino or Raspberry Pi, allowing users to build and customize robotic vehicles. However, in this study, the researchers used Arduino Uno as the programmable microcontroller. They are used in STEM education for teaching robotics, programming, and sensor integration, providing a hands-on way to explore autonomous vehicle concepts and robotic systems.

Figure 5. Programmable Car Set

f. L298N Motor Driver

The L298N Motor Driver is a module used to control the speed and direction of DC motors and stepper motors. It can handle higher currents and voltages than most microcontrollers, making it suitable for driving motors in robotics and other applications for automation projects.

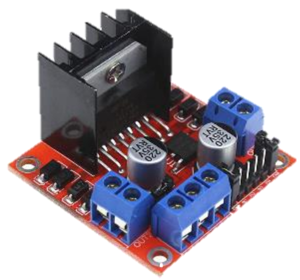

Figure 6. L298N Motor Driver

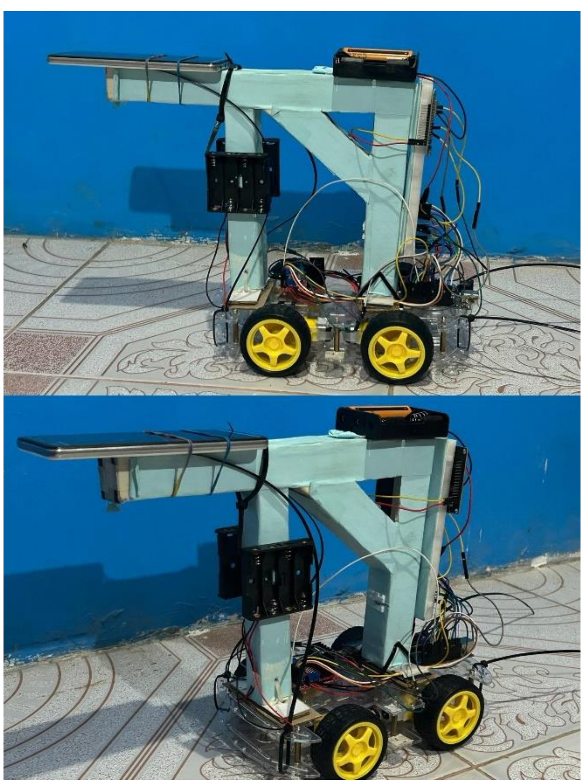

Figure 7. Final Project Design

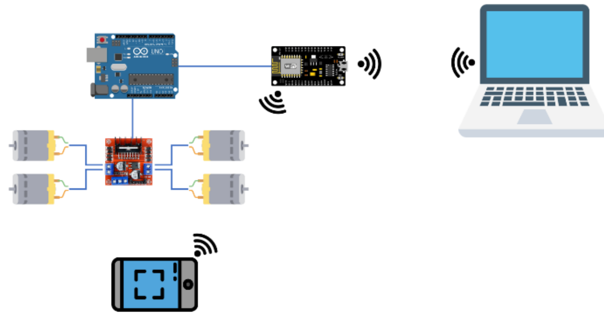

Figure 8. Components Diagram

This component diagram illustrates a line-following robot system. An Arduino UNO controls the motors via an L298N motor driver, with motor signals sent to four DC motors. Wireless communication is facilitated by an ESP8266 module, enabling machine learning automation using a laptop and smartphone.

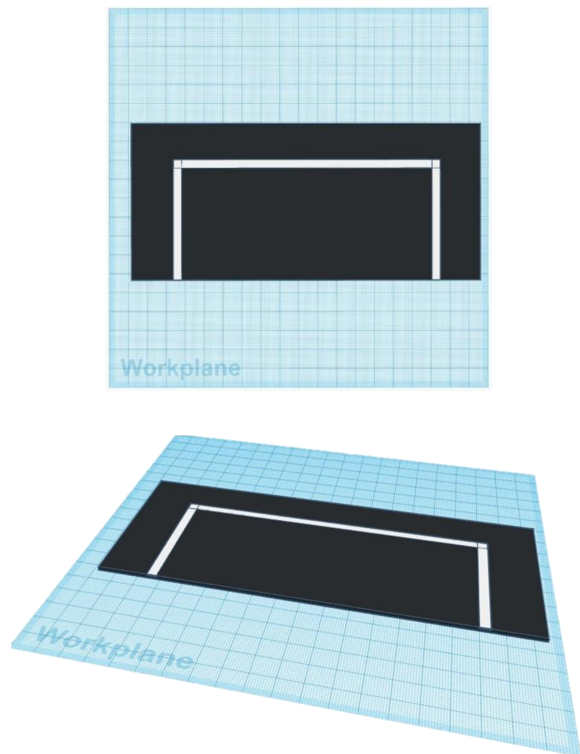

Figure 9. Environment

The environment plays a crucial role in the performance and reliability of a robot line follower integrated with a Teachable Machine model using an Arduino Uno.

Model Integration

Integrating a Teachable Machine into a robot line follower using an Arduino Uno involves several key steps. First, the Teachable Machine is used to train a model that can recognize various patterns or signals that the robot might encounter. This training involves capturing and labeling data, then exporting the model in a format compatible with Arduino. Next, the model is uploaded to the Arduino Uno. The Arduino is connected to sensors, such as the camera, that provide real-time input to the model. As the robot follows the line, the sensors capture data, which is processed by the Teachable Machine model running on the Arduino. The model's predictions help the Arduino determine the necessary adjustments to the robot's path, ensuring it stays on course. The final steps involve testing and fine-tuning the system to ensure reliable and accurate performance in various conditions.

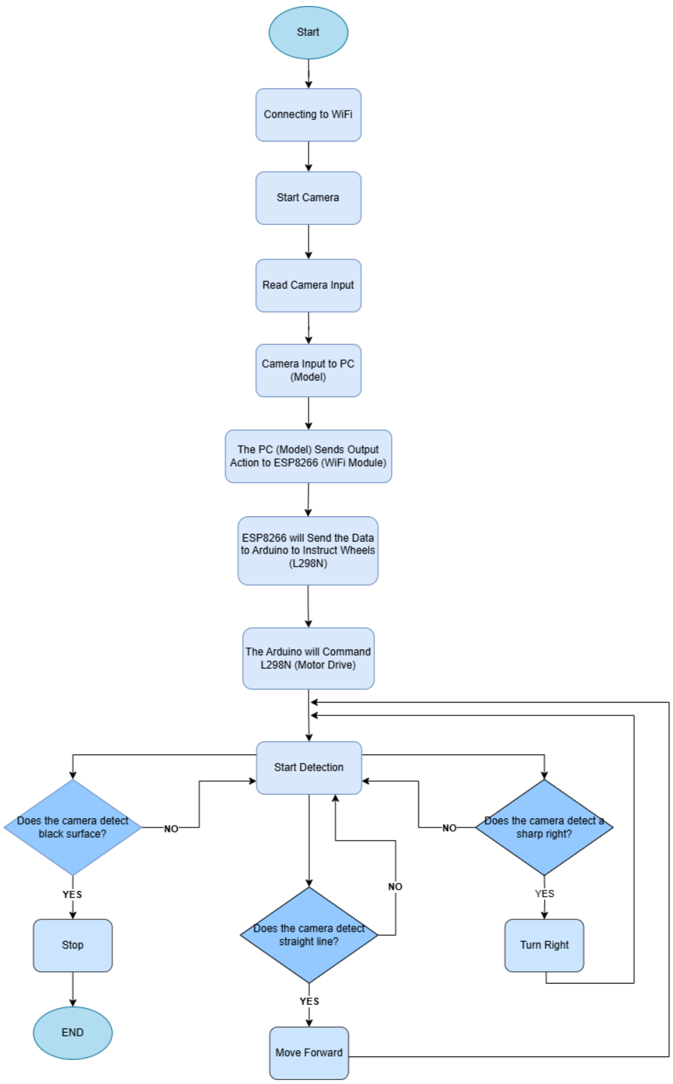

Figure 10. Flowchart

The process depicted in the flowchart outlines the operation of a camera-based navigation system, or what is called ‘the robot line follower’. It begins with establishing a WiFi connection, followed by starting the camera to capture visual input. This camera input is then sent to a PC for processing. The processed data is transmitted to an ESP8266 module via USB, which then communicates with an Arduino to control the wheels through an L298N motor driver. The system incorporates a security measure requiring two-factor or multi-factor authentication before proceeding. The system begins detection and checks if the camera detects a black surface. If it does, the system takes a "sharp right" turn; if not, it proceeds to the next step. It then checks if the camera detects a straight line. If it does, the system turns right; if not, it moves forward. In summary, this flowchart represents how a camera-based system processes visual input to control movement via WiFi communication.

IV. RESULT

The integration of Teachable Machine in a robot line follower using Arduino Uno demonstrated significant advancements in the robot's line-following capabilities. The primary objective was to explore the performance of the robot by utilizing teachable machine to recognize and follow lines more effectively. Through a series of experiments and iterations, the results showcased the feasibility and efficiency of this approach.

The following sections present a detailed analysis of the robot's performance, including the accuracy of line detection, response times, and the overall improvement in navigation compared to traditional line-following methods. The data collected highlights the strengths and potential limitations of using Teachable Machine with Arduino Uno in this context, providing valuable insights into the practical application of machine learning in robotics.

Provided below are sample outputs for determining and testing results derived from the model.

Table 1. Robot Testing and their Results

Camera Status	**Expected Result**	**Actual Result**	**Remarks**
Straight Line	Forward	Robot moves Forward	Success
Sharp Turn	Turn Right	Robot turns right	Success
Black Surface	Stop	Robot stops	Success

The results of testing a robot line follower with an integrated Teachable Machine model using an Arduino Uno are summarized in Table 1. The tests were conducted under three different camera statuses: straight line, sharp turn, and black surface. When the camera detected a straight line, the expected result was for the robot to move forward, which it successfully achieved. In the case of a sharp turn, the expected behavior was for the robot to turn right, and the robot correctly executed this action as well. Lastly, when the camera encountered a black surface, the robot was expected to stop, which it did successfully. Each test case resulted in the expected behavior being accurately performed by the robot, demonstrating the successful integration and functionality of the Teachable Machine model in guiding the robot's movements.

V. CONCLUSION AND FINDINGS

In conclusion, the integration of a Teachable Machine model into a robot line follower using an Arduino Uno has demonstrated significant success, showcasing the potential of combining machine learning with basic robotics. Through a series of tests, the robot consistently achieved the expected outcomes, confirming the effectiveness of the Teachable

Machine model in guiding the robot's actions. When the camera detected a straight line, the robot moved forward as anticipated. During a sharp turn, the robot accurately turned right, and upon encountering a black surface, it successfully came to a stop. These results, as summarized in Table 1, underline the model's capability to enhance the robot's ability to interpret and respond to various visual cues.

The findings from this project illustrate that even with the constraints of limited hardware resources, such as the Arduino Uno, advanced functionalities can be realized through the application of machine learning models. The successful implementation and testing indicate that the Teachable Machine model can significantly improve the robot's adaptability and performance in real-world scenarios. This integration not only enhances the robot's line-following abilities but also demonstrates the broader potential for machine learning to revolutionize robotic applications, making them more intelligent and responsive.

Furthermore, the project highlights the accessibility and practicality of using open-source tools and platforms, like Teachable Machine and Arduino, to develop sophisticated robotic systems. It opens up new avenues for educators, hobbyists, and researchers to explore the intersections of machine learning and robotics. By utilizing these technologies, future projects can build on this foundation to create even more complex and capable robotic systems, ultimately advancing the field of robotics and automation. This work underscores the transformative impact of integrating artificial intelligence with robotics, paving the way for innovative solutions across various industries and applications.

However, during the process of constructing and testing our line-following robot, we encountered several limitations and challenges. These issues provided valuable insights, and we believe that future researchers and developers aiming to build a similar robot can benefit from addressing them. By taking our experiences into account, they can create more efficient and reliable line-following robots.

1. Wrong Calibrations of Turns – The line-following robot relied on a manual trial-and-error approach to determine the correct timing for turns. This process is not only time-consuming but also prone to inaccuracies. To improve this, precise turn timing should be established to ensure that the robot consistently follows the environmental line without deviation.

2. Camera Problems – Initially, the team attempted to use an Arduino OV7670 camera. However, it proved too slow for processing tasks required in machine learning applications. Although a mobile phone camera sufficed for this project, the researchers recommend using a smaller, lighter, yet high-definition camera in future projects. This would enhance performance without compromising the robot's mobility and efficiency.

3. WiFi Module Short – The WiFi module accidentally short-circuited and needed replacement. To prevent this in the future, consider installing an on/off switch for the power source. This addition would eliminate the need to frequently disconnect and reconnect wires, thereby reducing the risk of short circuits and extending the lifespan of the components.

4. Durability of the Robot – The robot's architecture is quite unstable because of the soft materials used in its construction. To address this issue, it is advisable to invest in stronger, more durable materials. This will enhance the robot's structural integrity, ensuring greater stability and robustness during operation.

5. Limited Mobility – The robot's current capabilities are limited to making right turns on sharp curves, moving forward, and stopping. To improve its maneuverability, consider integrating specific components or algorithms, such as axis sensors. These enhancements would enable the robot to execute more precise and varied turns, improving its overall functionality and performance.

6. Limited Data Training – The model was trained using limited data. The researchers gathered data only for forward, turning right, and stop movement. To solve this problem, the researchers implement only in short lines, henceforth, the prototype was developed only to run in short lines with few turning parts.

7. Environment Guidelines – Instead of using sharp curves, it would be more beneficial to implement soft curves. This approach more accurately reflects the design of real-life roads, providing a more realistic and practical testing environment for the robot. Adapting to soft curves will improve the robot's ability to navigate real-world scenarios effectively.

All in all, the successful integration and testing of the Teachable Machine model with an Arduino Uno for a robot line follower project shows that even simple hardware can be made smarter with machine learning. This project not only proves the model works well but also opens the door for more innovative and intelligent robots in the future. By combining easy-to-use tools with advanced technology, researchers can create better robotic solutions that can be used in many different areas. These findings encourage more experiments and developments, showing that machine learning can greatly improve how robots perform their tasks. This project highlights the potential for machine learning to play a big role in making robots more autonomous and effective in various fields.

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